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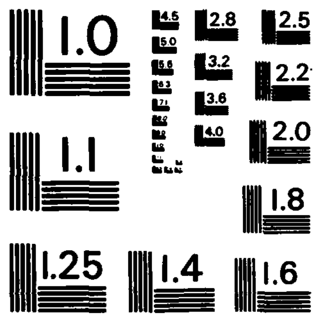

MICROCOPY RESOLUTION TEST CHART
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The concept of intrinsic age was introduced to relate the deterioration of a component under field conditions to the deterioration it would have experienced under laboratory conditions. Work has begus on research into random shapes. Additional research was performed on the stability of a harmonic oscillator in the presence of small noise.

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PROGRESS REPORT

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AFOSR GRANT No. 82-0189

MARKOV PROCESSES

APPLIED TO CONTROL, REPLACEMENT, AND SIGNAL ANALYSIS

for the period

1 June 1984 - 31 May 1985

Principal Investigator

E. ÇINLAR

Northwestern University Evanston, Illinois

This is a report on the work done under AFOSR Grant No. 82-0189 during 1 June 1984 to 31 May 1985. This report completes the report for the six-month period extending from 1 June 1984 to 31 December 1984, the latter report having been submitted earlier.

Much of this work has been of an exploratory nature. The main thrusts have been on the reliability of complex devices, on the problems of fatigue and fracture, and on the stochastic shapes that arise when manufacturing circles and cylinders. In addition, there has been some work on queues with batch services and on the stability of harmonic oscillators.

A. RELIABILITY OF COMPLEX DEVICES

Problems of reliability and maintenance and replacement have been difficult for probabilists facing multi-component devices. The difficulty is caused by the dependencies between the lifetimes of the components because of their common dependence on the environmental factors. Moreover, it has been difficult to find models that would somehow relate the quantities of interest to data that can be obtained by laboratory experiments.

We have introduced a concept, which we call intrinsic age, to relate the deterioration of a component under field conditions to the deterioration it would have experienced under laboratory conditions. Using the calculus we are building, this enables one to use the data obtained previously in laboratory in order to dynamically estimate the deterioration level of the device as the actual history of the environment unfolds itself.

The mathematical methods used turned out to have surprising connections with martingale theoretic treatment of multi-dimensional point processes. This work is still undergoing development.

In a related issue, that of optimal replacement policies for the components of a complex device, we have made better progress. For simplicity, we describe the work reported in the attached paper [1] in the case of a device with two components. The deterioration of two components is described by a two-dimensional Markov process, increasing in each dimension. The general form of such processes has been characterized in the earlier research under this grant by Çinlar [Markov and semimarkov models of deterioration; in Reliability Theory and Models; M. S. Abdel-Hameed, E. Çinlar, and J. Quinn, eds., Academic Press, 1984]. Suppose that replacing the first component costs $300, replacing the second $400, and replacing both $500. Note that there is real incentive to replace both components, even if only one has failed, if the age of the second component is great enough. In [1], the problem is treated carefully for an arbitrary number of components, the optimal policy is characterized, the computations are reduced to linear programming, and some sample problems are solved numerically. The form of the optimal policy contains some very interesting surprises.

B. DEFORMATIONS OF SOLIDS

This is a continuation of our work on the nucleation and growth of microcracks. This was modeled as a measure-valued Markov process, essentially capturing the evolution of the spatial configuration of

microcracks. We have been able to obtain expressions for the mean and variance of quantities that depend additively on the microcracks (quantities like stress, strain). However, the first passage time to a critical configuration is turning out to be very difficult.

C. RANDOM SHAPES

When we manufacture a circular disk or a cylinder, the outcome is a random shape that is approximately a circle or a cylinder. The deviation from the desired geometric object is called surface roughness and is the cause of much concern in tribology (in computing the oil pressures and load capacities of bearings) and in fracture mechanics (in studies of surface fatigue caused by microdents and notches).

We have a quintessential model for a random circle. It is Gaussian, rotationally invariant, reversible, and Markovian in the random field sense. Moreover, it is the unique such process. We have extended that model to random cylinders by coupling our random circle with an Ornstein-Uhlenbeck process along the cylinder's axis. Currently, we are studying the maximum processes associated with such shapes.

D. STABILITY OF HARMONIC OSCILLATORS

The problem is the stability of the harmonic oscillator in the presence of small noise, usually modelled as a Markov process which is stationary. In this paper [2], Pinsky examines the question assuming that the noise process is a Markov process with finitely many states. It is shown that, asymptotically, as time goes to infinity, there is always instability.

E. MISCELLANEOUS

In paper [3], a problem in queueing theory is considered, which problem has a certain bearing on the maintenance and replacement of complex devices. We describe the problem here in reliability terms. Suppose that a device is scheduled for inspections and repairs at times a,2a,3a,... . Those components that fail during (0,a) are repaired (and become as good as new) at time 2a, and so on. The problem is to figure out the average time spent in the failed state by a component. This problem is fairly easy and can be done by renewal theoretic considerations. The difficult problem solved in [3] is the more realistic case where the inspection-repair scheduled for na occurs in fact at a time $na + D_n$, where D_n represents the delay.

The book [4] is the proceedings of a conference on reliability theory, which was edited by the principal investigator together with M. S. Abdel-Hameed and J. Quinn.

The book [5] consists of about half of the papers presented at the 1983 Seminar on Stochastic Processes organized and edited by the principal investigator together with K. L. Chung and R. K. Getoor. These seminars are held every year.

The 1984 seminar proceedings are in press. The 1985 seminar proceedings are still under preparation.

F. PERSONNEL

During the period reported on, in addition to the principal investigator, Professor M. Pinsky was supported for one month during the summer of 1984 as a research associate, and Professor S. Ozekici was supported for ten months, 1/3 time, as a post-doctoral fellow.

G. OTHER ACTIVITIES

During this period, the principal investigator gave talks as follows:

1. Theory of Regerative Processes, an Overview. International Symposium on Semi-Markov Processes and Their Applications. Universite Libre de Bruxelles, June 1984, (Keynote Address).
2. A Measure Valued Markov Process. American Mathematical Society Meeting, Special Session on Stochastic Analysis and Related Topics, March 1985, Chicago, (Invited Paper).
3. Random Circles. Angewandte Stochastische Prozesse. Oberwolfach Mathematisches Forschungsinstitut, Germany, April 1985, (Invited Paper).
4. Reliability of Devices with Many Components. AFOSR Workshop on Reliability. Shenandoah, May 1985.

H. LIST OF WORK ATTACHED

[1] S. Ozekici. Optimal Periodic Replacement of Multicomponent Reliability Systems.

[2] M. Pinsky. Instability of the Harmonic Oscillator with Small Noise.

[3] S. Ozekici. Average Waiting Time in Queues with Scheduled Batch Services.

[4] M. S. Abdel-Hameed, E. Çinlar, J. Quinn, eds. Reliability Theory and Models, Academic Press, Orlando, 1984.

[5] E. Çinlar, K. L. Chung, R. K. Getoor, eds. Seminar on Stochastic Processes, 1983. Birkhauser, Boston, 1984.

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